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RADIATION PATTERN OF A LINEAR ARRAY WHOSE ELEMENTS ARE YAGI ANTENNAS

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ABSTRACT

A new a linear array is proposed with Yagi antennas as its elements. Using the moment method, the far field radiation pattern is calculated for the new array which is formed of Yagi monopoles over perfect ground plane. Investigation of the far Field radiation pattern is carried out for the cases of main lobe steering and pattern shaping (using Tschebyscheff polynomial). The effect of varying the frequency on the radiation pattern is also studied. Results show that the new linear array with Yagi monopole elements has larger gain and less reception from high altitudes than linear array with quarter-wavelength monopole whips.

1. Introduction

One of the important applications of ground wave radars in the area of ocean remote sensing is the detection and tracking of both ships and sea ice hazards. A long range radar system located at the coast uses a highly directional narrow beam in the azimuthal direction. To achieve this requirement a linear array is used where the half power beam width is equal to $50.4\lambda/L$ [1], where λ is the wavelength and L is array length. Usually, the array elements are quarter-wave length monopole whips over a ground plane. A major problem that exists with this array design is the high level of interference which is due to receiving unwanted signals either from high altitudes or from the back of the array (ground side). To reduce this interference, we suggest the replacement of the monopole whips by a three element Yagi monopole antennas, which have larger gain in the forward rather than the backward direction and less half power beam width in the E-plane than that of the monopole whips. Also, simplicity of construction and relatively high gain along its end-fire direction are some of the advantages of the Yagi antenna. Usually, the Yagi antenna is formed of a driver, and a reflector and/or a number of directors. Numerous graphical data [2] are available for investigating the effect of varying the Yagi's element diameter, element length, spacings between elements and overall length on the gain.

Array description

The array is formed of six monopoles with half wavelength separation over a ground plane. The array elements are three element Yagi monopoles where the lengths of the reflector, driver and director are 0.2395λ, 0.2265λ, and $0.2255\ \lambda$, respectively [4]. The elements whose diameters are 0.005λ have equal spacing of quarter wavelength as shown in Fig. 1. The Yagis are positioned such that their endfire directions coincide with the broadside direction of the main array. The wavelength λ is 44.444m corresponding to a frequency of 6.75MHz. The Numerical Electromagnetics Code (NEC) [3], which is based on the moment method is used to calculate the far field radiation pattern of the linear array with its wire elements. Two main investigations of the radiation pattern will be carried out on the linear array with the Yagi elements; i) for various frequencies, and ii) for

steering the main lobe of either a phased array (equal amplitude excitation) or a shaped pattern array (a Tschebyscheff amplitude distribution, 1:2.3:3:3:2.3:1, with a side lobe level of -30dB)

3. Discussion of numerical results

Figure 2 shows the polar plots of the far field radiation patterns for the six element linear phased array in two cases of elements' configurations, quarter-wavelength whips and three element Yagis as shown in Figure 1. The plots which contain both the E-plane and H-plane electric fields show the advantages of the array with Yagi elements over that with whips. These advantages include higher H-plane gain (18.93B compared to 14.13dB), narrower E-plane half power beam width for the monopole (25° compared to 38.5°) and a larger front-to-back lobe ratio (7.8 dB in comparison to unity). The effect of frequency variation on the array gain, H-plane half power beam width, relative side lobe level and the E-plane half power beam width has been studied around the design frequency of 6.75 MHz. It is found that the maximum overall gain which coincides with the maximum H-plane gain, decreases steadily as the frequency falls below the design frequency. Once the frequency exceeds the design value, the maximum overall gain starts having a vertical component, thus lifting the main lobe. Moreover, the E-plane half power beam width which is narrowest of 25° at design frequency widens with the increase in frequency.

At design frequency, the radiation pattern was calculated for the case of steering the array main lobe to 60° of the broadside direction as a phased array or as shaped beam array. It is found that the main beam becomes directed towards 50° rather than the designed direction of 60°. This lag in steering can be understood using pattern multiplication as the Yagi elements H-plane radiation pattern is not uniform as in the case of monopole whips.

4. Conclusion

Using a Yagi as array element rather than half wavelength linear antennas results in higher overall gain (increase signal to noise ratio), reduction in high altitude gain and noticeable difference between forward and back gains of the main lobes (reduction in interference and noise). These features are greatly desirable for ground wave radar antennas in coastal sites. It is also found that the azimuthal half power beam width is not generally affected by the geometrical configuration of the array elements.

References

1. R.C. Johnson and H. Jasik, *Antenna Engineering Handbook*, McGraw-Hill Book Co., 1984.

2. P. P. Vierbicke, " Yagi Antenna Design," *NBS Technical Note 688*, U.S. Dept. of Comm./Nat. Bur. of Stds, Dec. 1969.

3. G. J. Burke and A. J. Poggio, " Numerical Electromagnetics Code (NEC)- Method of Moments," Parts I and II, Technical Document 116, Naval Ocean Systems Center, San Diego, California, Revised January 1980.

1. W. L. Stutzman and G. A. Thiele, *Antenna Theory and design*, John Wiley & Sons, 1981.

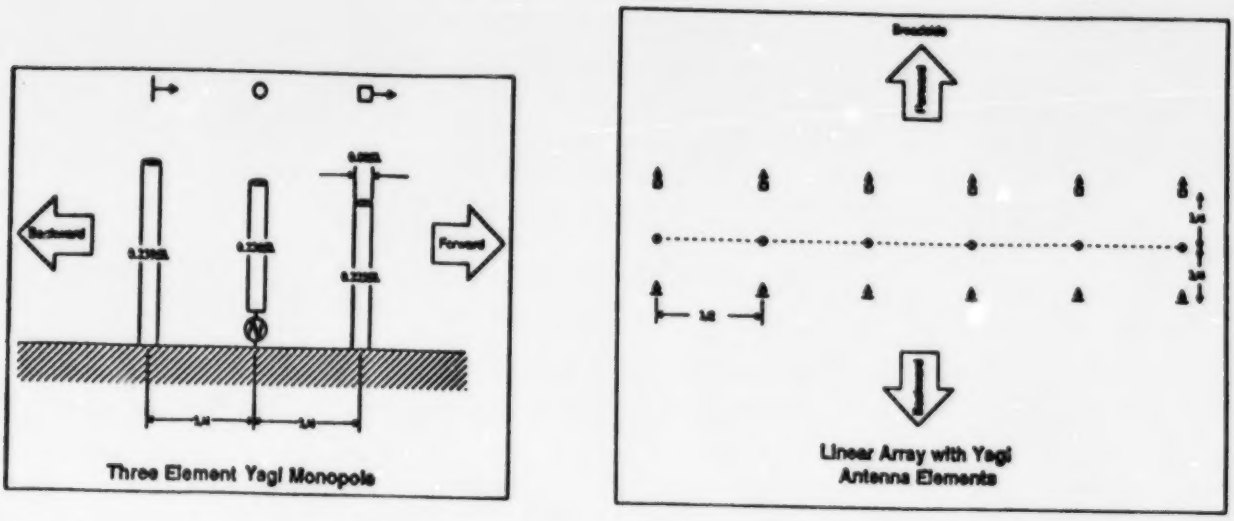

Fig. 1. Array geometrical configuration.

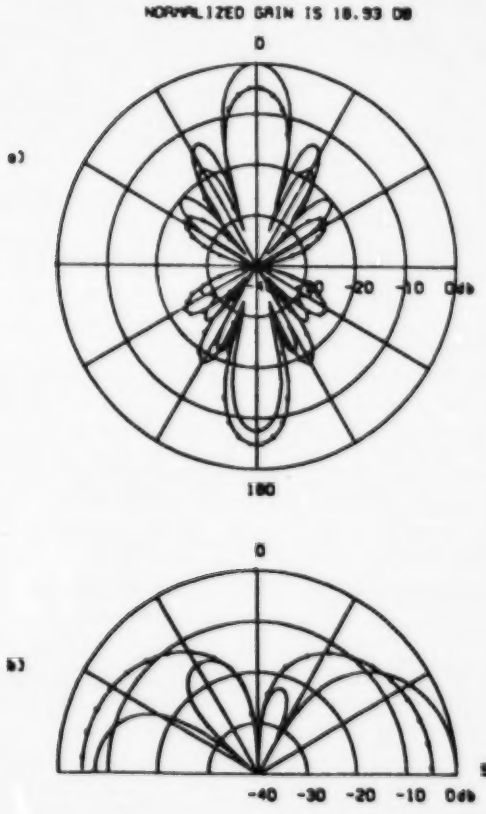

FIG. 2. Far field a) H-plane and b) E-plane radiation patterns for a linear array with Yagi elements(——) and quarter-wave length whips (-■-).